

Claims:

1. A process for reducing iron-ore-containing particulate material in an at least two-stage process performed in an apparatus comprising a plurality of reaction zones arranged consecutively in series and formed by a moving particulate material, the process comprising:

conducting a reducing gas through at least a first one of the reaction zones in the gas pathway and then through a second one of the reaction zones in the gas pathway consecutively in the series, the reaction zones in the gas pathway being gas pathway reaction zones;

moving particulate material consecutively through the series of reaction zones in the reverse sequence to the sequence of the conduction of reducing gas through the series of reaction zones, through a first one of reaction zones in a particulate pathway and then through a second one of the reaction zones in the particulate pathway, the reaction zones in particulate pathway being particulate pathway reaction zones;

heating the particulate material in the first particulate pathway reaction zone and reducing the particulate material in each of the further particulate pathway reaction zones consecutively in the series;

adding reducing gas to the first particulate pathway reaction zone and conditioning the reducing gas added to the first particulate pathway reaction zone for achieving a maximum pre-heating temperature thereof, whereby the reducing gas added to the first particulate pathway reaction zone is conditioned by at least one selected from increasing the degree of oxidation of the reducing gas, and decreasing the temperature of the reducing gas, or both carried out jointly, so that a range of no reduction to hardly any reduction occurs in the first particulate pathway reaction zone, the preheating being sufficient for causing a preheating temperature of the particulate material within the fringe range of starting of reduction, and adjusting a temperature level of at least 600°C in the second particulate pathway reaction zone for the particulate material and reducing iron-oxide-containing particulate material in that zone to wuestite.

2. The process of claim 1, wherein the temperature level in the second particulate pathway reactor zone is in the range of between 600 and 700°C.

3. The process of claim 1, wherein the temperature level in the second particulate pathway reactor zone is in the range of between 620 and 660°C.

4. A process for reducing metal-containing particulate material in an at least two-stage process performed in an apparatus comprising a plurality of reaction zones arranged consecutively in series and formed by a moving particulate material, the process comprising:

conducting a reducing gas through at least a first one of the reaction zones in the gas pathway and then through a second one of the reaction zones in the gas pathway consecutively in the series, the reaction zones in the gas pathway being gas pathway reaction zones;

moving particulate material consecutively through the series of reaction zones in the reverse sequence to the sequence of the conduction of reducing gas through the series of reaction zones, through a first one of reaction zones in a particulate pathway and then through a second one of the reaction zones in the particulate pathway, the reaction zones in particulate pathway being particulate pathway reaction zones;

heating the particulate material in the first particulate pathway reaction zone and reducing the particulate material in each of the further particulate pathway reaction zones consecutively in the series;

adding reducing gas to the first particulate pathway reaction zone and conditioning the reducing gas added to the first particulate pathway reaction zone for achieving a maximum pre-heating temperature thereof, whereby the reducing gas added to the first particulate pathway reaction zone is conditioned by at least one selected from increasing the degree of oxidation of the reducing gas, and decreasing the temperature of the reducing gas, or both carried out jointly, so that a range of no reduction to hardly any reduction occurs in the first particulate pathway reaction zone, the preheating being sufficient for causing a preheating temperature of the particulate material within the fringe range of starting of reduction, and

in the first particulate pathway reaction zone, removing oxygen at a maximum maintained reduction speed of 0.2% oxygen removal per minute.

5. The process of claim 4, wherein the maximum maintained reduction speed is 0.05% oxygen removal per minute.

6. The process of claim 4, wherein iron ore is the particulate material.

7. A process according to claim 1, further comprising, in the first particulate pathway reaction zone, adjusting the temperature level for the particulate material in the first particulate pathway reaction zone with aid of the caloric content of the reducing gas to a temperature at which reduction of the particulate material would occur, and avoiding reduction at that temperature level by increasing the degree of oxidation of the reducing gas to an extent such that in the first particulate pathway reaction zone, in the range of no reduction to hardly any reduction occurs.

8. A process according to claim 4, further comprising, in the first particulate pathway reaction zone, adjusting the temperature level for the particulate material in the first particulate pathway reaction zone with aid of the caloric content of the reducing gas to a temperature at which reduction of the particulate material would occur, and avoiding reduction at that temperature level by increasing the degree of oxidation of the reducing gas to an extent such that in the first particulate pathway reaction zone, in the range of no reduction to hardly any reduction occurs.

9. A process according to claim 1, wherein the adjustment of the temperature level and the increase of the degree of oxidation are conducted independently of introduction of any fresh reducing gas used for reducing the particulate material, while avoiding the exertion of any influence on the composition and temperature of the reducing gas that is freshly added to the particulate material for final reduction.

10. A process according to claim 4, wherein the adjustment of the temperature level and the increase of the degree of oxidation are conducted independently of introduction of any fresh reducing gas used for reducing the particulate material, while avoiding the exertion of any influence on the composition and temperature of the reducing gas that is freshly added to the particulate material for final reduction.

11. A process according to claim 1, wherein the particulate material is a fine particulate material having a particle size of up to 12 mm and is treated either in the form of monograins or in the form of a grain strip.

12. A process according to claim 4, wherein the particulate material is a fine particulate material having a particle size of up to 12 mm and is treated either in the form of monograins or in the form of a grain strip.

13. A process according to claim 1, further comprising adjusting the temperature level in the first particulate pathway reaction zone to be between 350 and 550°C.

14. A process according to claim 4, further comprising adjusting the temperature level in the first particulate pathway reaction zone to be between 350 and 550°C.

15. A process according to claim 1, wherein in the second particulate pathway reaction zone for the particulate material, a respective temperature level, which is lower as compared with the unaffected heating exchange, is adjusted.

16. A process according to claim 4, wherein in the second particulate pathway reaction zone for the particulate material, a respective temperature level, which is lower as compared with the unaffected heating exchange, is adjusted.

17. A process according to claim 1, further comprising, adjusting the temperature level in the first particulate pathway reaction zone for the particulate material by injecting H₂O in liquid or vapor form into the first particulate pathway reaction zone or into reducing gas supplied to the first particulate pathway reaction zone.

18. A process according to claim 4, further comprising, adjusting the temperature level in the first particulate pathway reaction zone for the particulate material by injecting H₂O in liquid or vapor form into the first particulate pathway reaction zone or into reducing gas supplied to the first particulate pathway reaction zone.

19. A process according to claim 1, further comprising, adjusting the temperature level in the first particulate pathway reaction zone for the particulate material by admixing a cold gas in the first particulate pathway reaction zone or in the reducing gas supplied to the first particulate pathway reaction zone.

20. A process according to claim 19, wherein the mixing of cold gas comprises admixing cold CO₂ or a cold reducing gas.

21. A process according to claim 4, further comprising, adjusting the temperature level in the first particulate pathway reaction zone for the particulate material by admixing a cold gas in the first particulate pathway reaction zone or in the reducing gas supplied to the first particulate pathway reaction zone.

22. A process according to claim 21, wherein the mixing of cold gas comprises admixing cold CO₂ or a cold reducing gas.

23. A process according to claim 1, wherein adjusting the degree of oxidation of the reducing gas in the first particulate pathway reaction zone comprises supplying vaporous or liquid H₂O into the first particulate pathway reaction zone or into the reducing gas supplied to the first particulate pathway reaction zone.

24. A process according to claim 4, wherein adjusting the degree of oxidation of the reducing gas in the first particulate pathway reaction zone comprises supplying vaporous or liquid H₂O into the first particulate pathway reaction zone or into the reducing gas supplied to the first particulate pathway reaction zone.

25. A process according to claim 1, wherein adjusting the degree of oxidation of the reducing gas in the first particulate pathway reaction zone comprises supplying CO₂ or CO₂ and H₂O mixtures into the first particulate pathway reaction zone or into the reducing gas supplied to the first particulate pathway reaction zone.

26. A process according to claim 4, wherein adjusting the degree of oxidation of the reducing gas in the first particulate pathway reaction zone comprises supplying CO₂ or CO₂ and H₂O mixtures into the first particulate pathway reaction zone or into the reducing gas supplied to the first particulate pathway reaction zone.

27. A process according to claim 1, further comprising maintaining an average retention time for the particulate material in the first particulate pathway reaction zone of up to forty minutes.

28. A process according to claim 4, further comprising maintaining an average retention time for the particulate material in the first particulate pathway reaction zone of up to forty minutes.

29. A process according to claim 1, further comprising, adjusting a temperature level in the last one of the particulate pathway reaction zones in the range of between 760 and 850°C.

30. A process according to claim 4, further comprising, adjusting a temperature level in the last one of the particulate pathway reaction zones for in the range of between 760 and 850°C.

31. A process according to claim 1, further comprising, in the second particulate pathway reaction zone for the particulate material, adjusting a degree of oxidation for the imminent formation of wuestite by selecting at least one of:

varying the degree of oxidation of fresh reducing gas introduced into one of the particulate pathway reaction zones;

adjusting the temperature of the reducing gas;

adjusting the retention time in one of the particulate pathway reaction zones following the second particulate pathway reaction zone;

adjusting the reducing gas by a specific amount; and

adjusting the composition of the reducing gas including varying the content of methane or the content of inert gas in the reducing gas.

32. A process according to claim 4, further comprising, in the second particulate pathway reaction zone for the particulate material, adjusting a degree of oxidation for the imminent formation of wuestite by selecting at least one of:

varying the degree of oxidation of fresh reducing gas introduced into one of the particulate pathway reaction zones;

adjusting the temperature of the reducing gas;

adjusting the retention time in one of the particulate pathway reaction zones following the second particulate pathway reaction zone;

adjusting the reducing gas by a specific amount; and

adjusting the composition of the reducing gas including varying the content of methane or the content of inert gas in the reducing gas.

33. A process according to claim 1, wherein reducing gas emerges from the second particulate pathway reaction zone, the process further comprising cooling and scrubbing that reducing gas, then introducing that reducing gas partially into the first particulate pathway reaction zone.

34. A process according to claim 4, wherein reducing gas emerges from the second particulate pathway reaction zone, the process further comprising cooling and scrubbing that reducing gas, then introducing that reducing gas partially into the first particulate pathway reaction zone.

35. A process according to claim 1, wherein reducing gas emerges from the first particulate pathway reaction zone, the process further comprising recirculating reducing gas emerging from the first particulate pathway reaction zone at least partially back into the first particulate pathway reaction zone.

36. A process according to claim 4, wherein reducing gas emerges from the first particulate pathway reaction zone, the process further comprising recirculating reducing gas emerging from the first particulate pathway reaction zone at least partially back into the first particulate pathway reaction zone.

37. A process according to claim 1, wherein the reducing gas has a CO content under 20%.

38. A process according to claim 1, further comprising adjusting the reducing gas for the first particulate pathway reaction zone to provide a vapor/carbon ratio ranging from 2.5 to 5.

39. A process according to claim 1, wherein when a supply of metal containing particulate material is interrupted, cooling the temperature in the reaction zones by regulating temperature of the reducing gas or by injecting H₂O or CO₂.